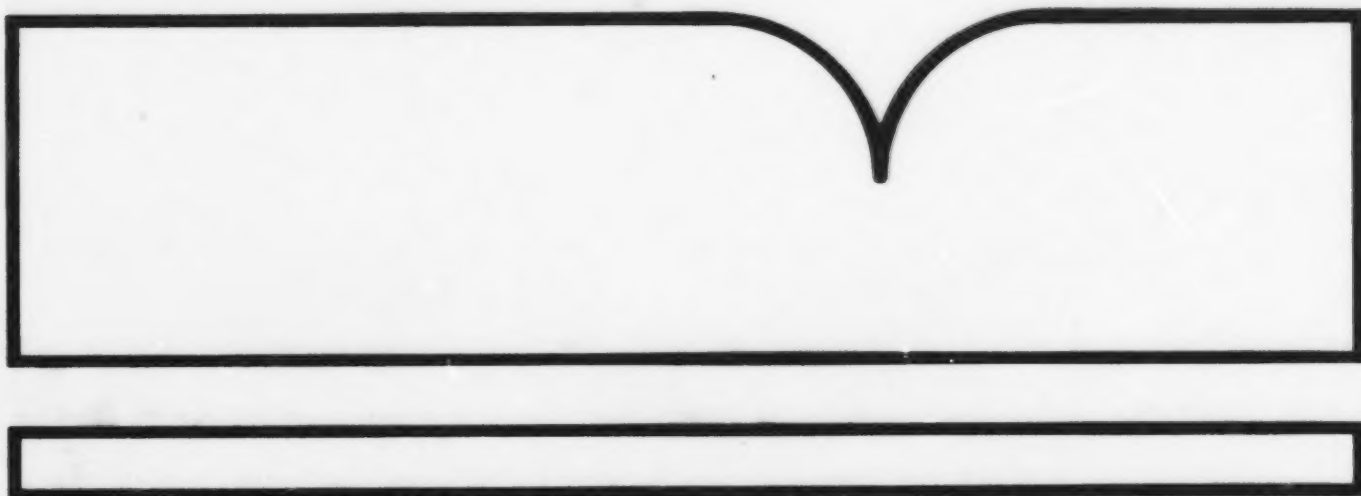


Amendments to the Report on Development of a
Highway Driving Cycle for Fuel
Economy Measurements

(U.S.) Environmental Protection Agency
Ann Arbor, MI

Apr 74



U.S. Department of Commerce
National Technical Information Service

NTIS

Amendments to the Report on
Development of a Highway Driving Cycle
for Fuel Economy Measurements

by

C. Don Paulsell

April, 1974

Environmental Protection Agency
Office of Air Programs
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Procedures Development Branch
Ann Arbor, Michigan

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16. ABSTRACT This report addresses several changes which have been made to the highway driving cycle described in the report entitled "Development of a Highway Driving Cycle for Fuel Economy Measurements", dated March 1974 (EPA-AA-ECTD-74-1). The purpose of this report is to explain the reasons for modifying the driving cycle and to summarize the characteristics of the updated tabulation of the cycle. The objective of this report is to produce an amended speed versus time tabulation of the highway driving cycle that is compatible with all chassis dynamometers.		
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Introduction:

This report addresses several changes which have been made to the highway driving cycle described in the report entitled, "Development of a Highway Driving Cycle for Fuel Economy Measurements," dated March, 1974.

Purpose:

The purpose of this report is to explain the reasons for modifying the driving cycle and to summarize the characteristics of the updated tabulation of the cycle.

Objective:

The objective of this report is to produce an amended speed versus time tabulation of the highway driving cycle that is compatible with all chassis dynamometers.

Background:

The initial tabulation of the highway driving cycle was derived in a three step process. The speeds were read from the actual trace at .1 inch intervals, each interval representing 1.5 seconds. This file was recomputed by a linear interpolation to yield a file with speeds for each .5 second interval. By deleting every other point from this .5 second file, a tabulation of speed versus time was constructed at 1.0 second intervals.

The characteristics of the various segments of the cycle were computed from the "1.5" second file and were published as Table 3 in the March, 1974 report on cycle development.

Several organizations that have used the highway driving cycle (1.0 second tabulation) reported that the initial acceleration and final deceleration rates were high enough to cause belt slippage on dynamometers with belt-driven inertia weights. Calculations show that the rates were about 4.9 mph/sec.

The MSAPC laboratory has had no problems driving the cycle on the direct-drive dynamometers. However, our experience with the development of the LA-4 on belt-driven dynamometers supports the problem cited above. The accelerations and decelerations on the LA-4 were normalized to 3.3 mph/sec or less to avoid the slippage and wear problems.

This precedent has been applied to the highway driving cycle to permit the use of this cycle on all existing equipment without causing abnormal slippage and wear.

It was also reported that a summation of the (1.0 second) speed versus time list did not agree exactly with the values shown in Table 3. Although the differences were very small, this report will summarize the characteristics for the updated speed-time tabulation.

Discussion of Amendments:

It was agreed among the engineers involved in the cycle development that changes should be made only to the segments that were above the 3.3 mph/sec limit rather than a simple linearization to 0 mph at each end of the trace. Table A shows the tabulations of the two versions to illustrate which speeds were changed. Two seconds were added to the acceleration and a one second shift was made on the deceleration profile.

After these changes were made, a summation of the entire file was computed for each segment and for the total cycle. This exercise revealed the reason for the disparity between Table 3 and the summary of the tabulated speeds. The values in Table 3 were computed from the (1.5 second) file of speed versus time. In that file, two segments, C and B ended on half seconds; therefore, these points were not shown in the (1.0 second) tabulation.

This difference and the fact that the composite of Table 3 is simply a summation of the four segments produces a small variation in the final numbers.

Because the official version of the highway driving cycle will be the one second tabulation of speed versus time, the appropriate summary of characteristics should be based on this tabulation. This summary has been made. The values have been shown in parentheses with the previous values of Table 3 for comparison. Note that the average speed is now based on total sample time rather than total driving time. This value has no impact on the calculation of fuel economy.

The value of major impact on the calculation of fuel economy is the total distance traveled. The new value of 10.242 miles differs by + .16% from the previous value of 10.225. This updated value reflects the increase in time and the changes in speeds made to normalize the acceleration and deceleration rates.

Conclusions and Recommendations:

The changes which have been made to the highway driving cycle should permit its use without problems. The updated tabulation dated (Monday April 22, 1974) is recommended for adoption as the official driving cycle for highway fuel economy measurements.

The magnitude of the changes which have been incorporated into the updated version are not significant enough to invalidate any tests which have been performed using the previous version. It is recommended that previous measurements be accepted as valid and equivalent indications of highway fuel economy.

TABLE A

***** EPA HIGHWAY FUEL ECONOMY DRIVING CYCLE *****
 *** SPEED (MPH) VS TIME (SEC) ***

ORIGINAL CYCLE MARCH 1974		AMENDED CYCLE MON APR 22/74		
SEC	MPH	SEC	MPH	
0	SAMPLE ON	0	SAMPLE ON	INITIAL ACCELERATION
1	0.0	1	0.0	
2	0.0	2	0.0	
3	4.7	3	2.0	
4	9.6	4	4.9	
5	14.5	5	8.1	
6	17.4	6	11.3	
7	19.8	7	14.5	
8	21.8	8	17.3	
		9	19.6	
		10	21.8	
743	42.5	745	42.5	FINAL DECCELERATION
744	40.2	746	39.2	
745	36.7	747	35.9	
746	32.0	748	32.6	
747	28.0	749	29.3	
		750	26.8	NEW POINT
748	24.5	751	24.5	
749	21.5	752	21.5	
750	19.5	753	19.5	
751	17.4	754	17.4	
752	15.1	755	15.1	
753	12.4	756	12.4	
754	9.7	757	9.7	
755	7.0	758	7.0	
756	5.0	759	5.0	
757	3.3	760	3.3	
758	2.0	761	2.0	
759	0.7	762	0.7	
760	0.0	763	0.0	
761	0.0	764	0.0	
762	SAMPLE OFF	765	SAMPLE OFF	

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TABLE 3

Characteristics of Composite Highway Driving Cycle*

Segment Length (IN)	Segment	Average Speed (MPH)	Distance Traveled (Miles)	Elapsed Time (MIN) (SEC)	% Total Miles
9.5 (0.13)	(Idle)	(0.0)	(0.0)	2	(0.0)
11.5 (9.60)	D	41.157 (40.736)	1.629 (1.629)	2.375 144	15.93 (15.91)
17.0 (11.53)	C	43.841 (43.835)	2.101 (2.107)	2.875 173	20.55 (20.57)
12.5 (17.00)	A	56.096 (56.110)	3.973 (3.974)	4.250 255	38.85 (38.80)
12.5 (12.60)	B	48.421 (48.230)	2.522 (2.532)	3.125 189	24.67 (24.72)
50.5 (0.13)	(Idle)	(0.0)	(0.0)	2	(0.0)
50.5 (51.0)	Overall	48.595 (48.200)	10.225 (10.242)	12.625 765	100.0% (100.0%)
Inches	Total	MPH	Miles	Minutes Seconds (12.750)	

NOTE: Previous overall average speed did not include 4 second idle period.

*Values applicable to the amended version (Mon. April 22, 1974) are shown in parentheses.

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***** EPA HIGHWAY FUEL ECONOMY DRIVING CYCLE *****
 *** SPEED (MPH) VS TIME (SEC) ***

SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH
0	SAMPLE ON	50	38.6	100	48.5	150	44.1	200	43.4	250	48.0	300	33.4	350	59.0		
1	0.0	51	39.3	101	48.8	151	44.3	201	43.2	251	48.0	301	35.6	351	58.9		
2	0.0	52	40.0	102	49.1	152	44.4	202	43.2	252	48.0	302	37.5	352	58.8		
3	2.0	53	40.7	103	49.2	153	44.6	203	43.1	253	48.1	303	39.1	353	58.6		
4	4.9	54	41.4	104	49.1	154	44.7	204	43.0	254	48.2	304	40.2	354	58.4		
5	8.1	55	42.2	105	49.1	155	44.9	205	43.0	255	48.2	305	41.1	355	58.2		
6	11.3	56	42.9	106	49.0	156	45.2	206	43.1	256	48.1	306	41.8	356	58.1		
7	14.5	57	43.5	107	49.0	157	45.7	207	43.4	257	48.6	307	42.4	357	58.0		
8	17.3	58	44.0	108	49.1	158	45.9	208	43.9	258	48.9	308	42.8	358	57.9		
9	19.6	59	44.3	109	49.2	159	46.3	209	44.0	259	49.1	309	43.3	359	57.6		
10	21.8	60	44.5	110	49.3	160	46.8	210	43.5	260	49.1	310	43.8	360	57.4		
11	24.0	61	44.8	111	49.4	161	46.9	211	42.6	261	49.1	311	44.3	361	57.2		
12	25.8	62	45.0	112	49.5	162	47.0	212	41.5	262	49.1	312	44.7	362	57.1		
13	27.1	63	45.0	113	49.5	163	47.1	213	40.7	263	49.1	313	45.0	363	57.0		
14	28.0	64	45.1	114	49.5	164	47.6	214	40.0	264	49.0	314	45.2	364	57.0		
15	29.0	65	45.4	115	49.4	165	48.0	215	40.0	265	48.9	315	45.4	365	56.9		
16	30.0	66	45.7	116	49.1	166	48.0	216	40.3	266	48.2	316	45.5	366	56.9		
17	30.7	67	46.0	117	48.9	167	48.0	217	41.0	267	47.7	317	45.8	367	56.9		
18	31.5	68	46.3	118	48.6	168	47.9	218	42.0	268	47.5	318	46.0	368	57.0		
19	32.2	69	46.5	119	48.4	169	47.8	219	42.7	269	47.2	319	46.1	369	57.0		
20	32.9	70	46.8	120	48.1	170	47.3	220	43.1	270	46.7	320	46.5	370	57.0		
21	33.5	71	46.9	121	47.7	171	46.7	221	43.2	271	46.2	321	46.8	371	57.0		
22	34.1	72	47.0	122	47.4	172	46.2	222	43.4	272	46.0	322	47.1	372	57.0		
23	34.6	73	47.1	123	47.3	173	45.9	223	43.9	273	45.8	323	47.7	373	57.0		
24	34.9	74	47.2	124	47.5	174	45.7	224	44.3	274	45.6	324	48.3	374	57.0		
25	35.1	75	47.3	125	47.8	175	45.5	225	44.7	275	45.4	325	49.0	375	57.0		
26	35.7	76	47.3	126	47.9	176	45.4	226	45.1	276	45.2	326	49.7	376	57.0		
27	35.9	77	47.1	127	48.0	177	45.3	227	45.4	277	45.0	327	50.3	377	56.9		
28	35.8	78	47.0	128	47.9	178	45.0	228	45.8	278	44.7	328	51.0	378	56.8		
29	35.3	79	46.9	129	47.9	179	44.0	229	46.5	279	44.5	329	51.7	379	56.5		
30	34.9	80	46.9	130	47.9	180	43.1	230	46.9	280	44.2	330	52.4	380	56.2		
31	34.5	81	46.9	131	48.0	181	42.2	231	47.2	281	43.5	331	53.1	381	56.0		
32	34.6	82	47.0	132	48.0	182	41.5	232	47.4	282	42.8	332	53.8	382	56.0		
33	34.8	83	47.1	133	48.0	183	41.5	233	47.3	283	42.0	333	54.5	383	56.0		
34	35.1	84	47.1	134	47.9	184	42.1	234	47.3	284	40.1	334	55.2	384	56.1		
35	35.7	85	47.2	135	47.3	185	42.9	235	47.2	285	38.6	335	55.8	385	56.4		
36	36.1	86	47.1	136	46.0	186	43.5	236	47.2	286	37.5	336	56.4	386	56.7		
37	36.2	87	47.0	137	43.3	187	43.9	237	47.2	287	35.8	337	56.9	387	56.9		
38	36.5	88	46.9	138	41.2	188	43.6	238	47.1	288	34.7	338	57.0	388	57.1		
39	36.7	89	46.5	139	39.5	189	43.3	239	47.0	289	34.0	339	57.1	389	57.3		
40	36.9	90	46.3	140	39.2	190	43.0	240	47.0	290	33.3	340	57.3	390	57.4		
41	37.0	91	46.2	141	39.0	191	43.1	241	46.9	291	32.5	341	57.6	391	57.4		
42	37.0	92	46.3	142	39.0	192	43.4	242	46.8	292	31.7	342	57.8	392	57.2		
43	37.0	93	46.5	143	39.1	193	43.9	243	46.9	293	30.6	343	58.0	393	57.0		
44	37.0	94	46.9	144	39.5	194	44.3	244	47.0	294	29.6	344	58.1	394	56.9		
45	37.0	95	47.1	145	40.1	195	44.6	245	47.2	295	28.8	345	58.4	395	56.6		
46	37.0	96	47.4	146	41.0	196	44.9	246	47.5	296	28.4	346	58.7	396	56.3		
47	37.1	97	47.7	147	42.0	197	44.8	247	47.9	297	28.6	347	58.8	397	56.1		
48	37.3	98	48.0	148	43.1	198	44.4	248	48.0	298	29.5	348	58.9	398	56.4		
49	37.8	99	48.2	149	43.7	199	43.9	249	48.0	299	31.4	349	59.0	399	56.7		

SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH	SEC	MPH
400	57.1	450	58.2	500	54.7	550	55.8	600	48.3	650	50.2	700	54.2	750	26.8				
401	57.5	451	58.1	501	54.6	551	55.6	601	48.0	651	50.7	701	54.5	751	24.5				
402	57.8	452	58.0	502	54.4	552	55.4	602	47.9	652	51.1	702	54.8	752	21.5				
403	58.0	453	58.0	503	54.3	553	55.2	603	47.8	653	51.7	703	55.0	753	19.5				
404	58.0	454	58.0	504	54.3	554	55.1	604	47.7	654	52.2	704	55.5	754	17.4				
405	58.0	455	58.0	505	54.2	555	55.0	605	47.9	655	52.5	705	55.9	755	15.1				
406	58.0	456	58.0	506	54.1	556	54.9	606	48.3	656	52.1	706	56.1	756	12.4				
407	58.0	457	58.0	507	54.1	557	54.6	607	49.0	657	51.6	707	56.3	757	9.7				
408	58.0	458	57.9	508	54.1	558	54.4	608	49.1	658	51.1	708	56.4	758	7.0				
409	57.9	459	57.9	509	54.0	559	54.2	609	49.0	659	51.0	709	56.5	759	5.0				
410	57.8	460	58.0	510	54.0	560	54.1	610	48.9	660	51.0	710	56.7	760	3.3				
411	57.7	461	58.1	511	54.0	561	53.8	611	48.0	661	51.1	711	56.9	761	2.0				
412	57.7	462	58.1	512	54.0	562	53.4	612	47.1	662	51.4	712	57.0	762	0.7				
413	57.8	463	58.2	513	54.0	563	53.3	613	46.2	663	51.7	713	57.3	763	0.0				
414	57.9	464	58.3	514	54.0	564	53.1	614	46.1	664	52.0	714	57.7	764	0.0				
415	58.0	465	58.3	515	54.0	565	52.9	615	46.1	665	52.2	715	58.2	765	SAMPLE OFF				
416	58.1	466	58.3	516	54.0	566	52.6	616	46.2	666	52.5	716	58.8						
417	58.4	467	58.2	517	54.1	567	52.4	617	46.9	667	52.8	717	59.1						
418	58.9	468	58.1	518	54.2	568	52.2	618	47.8	668	52.7	718	59.2						
419	59.1	469	58.0	519	54.5	569	52.1	619	49.0	669	52.6	719	59.1						
420	59.4	470	57.8	520	54.4	570	52.0	620	49.7	670	52.3	720	58.8						
421	59.8	471	57.5	521	54.9	571	52.0	621	50.6	671	52.3	721	58.5						
422	59.9	472	57.1	522	55.0	572	52.0	622	51.5	672	52.4	722	58.1						
423	59.9	473	57.0	523	55.1	573	52.0	623	52.2	673	52.5	723	57.7						
424	59.8	474	56.6	524	55.2	574	52.1	624	52.7	674	52.7	724	57.3						
425	59.6	475	56.1	525	55.2	575	52.0	625	53.0	675	52.7	725	57.1						
426	59.4	476	56.0	526	55.3	576	52.0	626	53.6	676	52.4	726	56.8						
427	59.2	477	55.8	527	55.4	577	51.9	627	54.0	677	52.1	727	56.5						
428	59.1	478	55.5	528	55.5	578	51.6	628	54.1	678	51.7	728	56.2						
429	59.0	479	55.2	529	55.6	579	51.4	629	54.4	679	51.1	729	55.5						
430	58.9	480	55.1	530	55.7	580	51.1	630	54.7	680	50.5	730	54.6						
431	58.7	481	55.0	531	55.8	581	50.7	631	55.1	681	50.1	731	54.1						
432	58.6	482	54.9	532	55.9	582	50.3	632	55.4	682	49.8	732	53.7						
433	58.5	483	54.9	533	56.0	583	49.9	633	55.4	683	49.7	733	53.2						
434	58.4	484	54.9	534	56.0	584	49.3	634	55.0	684	49.6	734	52.9						
435	58.4	485	54.9	535	56.0	585	48.7	635	54.5	685	49.5	735	52.5						
436	58.3	486	54.9	536	56.0	586	48.2	636	53.6	686	49.5	736	52.0						
437	58.2	487	54.9	537	56.0	587	48.1	637	52.5	687	49.7	737	51.3						
438	58.1	488	55.0	538	56.0	588	48.0	638	50.2	688	50.0	738	50.5						
439	58.0	489	55.0	539	56.0	589	48.0	639	48.2	689	50.2	739	49.5						
440	57.9	490	55.0	540	56.0	590	48.1	640	46.5	690	50.6	740	48.5						
441	57.9	491	55.0	541	56.0	591	48.4	641	46.2	691	51.1	741	47.6						
442	57.9	492	55.0	542	56.0	592	48.9	642	46.0	692	51.6	742	46.8						
443	57.9	493	55.0	543	56.0	593	49.0	643	46.0	693	51.9	743	45.6						
444	57.9	494	55.1	544	56.0	594	49.1	644	46.3	694	52.0	744	44.2						
445	58.0	495	55.1	545	56.0	595	49.1	645	46.4	695	52.1	745	42.5						
446	58.1	496	55.0	546	56.0	596	49.0	646	47.5	696	52.4	746	39.2						
447	58.1	497	54.9	547	55.9	597	49.0	647	48.2	697	52.9	747	35.9						
448	58.2	498	54.9	548	55.9	598	48.9	648	48.8	698	53.3	748	32.6						
449	58.2	499	54.8	549	55.9	599	48.6	649	49.5	699	53.7	749	29.3						

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